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ECONOMETRICS AND ECONOMIC-MATHEMATICAL METHODS AND MODELS IN LOGISTICS

The article examines the use of mathematical models in logistics to optimize various aspects of operation, including inventory management, production planning, routing and warehouse management. Analyzes the types of mathematical models used in logistics and describes the stages of their creation and application. The article highlights the role of mathematical models in making data-driven decisions, optimizing resources and reducing costs. The importance of proper selection of mathematical tools and data quality to obtain realistic and applicable results is also noted.
***Keywords**: mathematical models, logistics, optimization, inventory management, production planning, routing, warehouse management, econometrics*

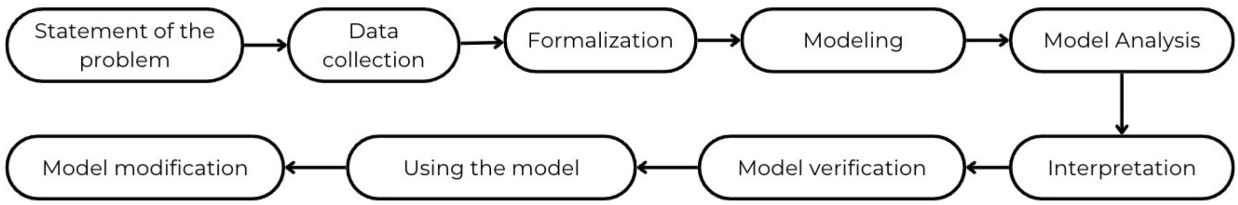
Consideration of logistics through mathematical models allows us to quantify and optimize various aspects of logistics operations. Mathematical models in logistics are used to model supply chains, inventory management, production planning, routing and transport planning, and warehouse management. Types of mathematical models used in logistics: linear programming, integer programming, discrete event modeling, queuing theory, geometric programming.

The use of mathematical models in logistics helps improve data-based decision making, optimize resources and reduce costs, increase transparency and control over logistics operations, as well as the ability to play various scenarios and predict results. However, models can be complex and require large amounts of data and skilled professionals to develop and interpret the models. Also raising the issue of logistics, we understand that real logistics systems can be dynamic and unpredictable, but despite various kinds of limitations, mathematical models are an important tool for analyzing and optimizing logistics operations, which contributes to making informed decisions, increasing efficiency and reducing costs.

Touching upon the issue of practical tasks of economic and mathematical modeling in logistics, we understand that they include the process of analyzing economic objects and processes, forecasting, as well as identifying management decisions based on the entire analysis [1].

Next, consider the diagram of the economic-mathematical modeling process shown in Figure.

Economic-mathematical modeling process



Note – Source: own development.

Thus, our first stage is the formulation of the problem, which includes defining the goals of modeling, identifying the object of study (for example, demand for goods, efficiency of logistics processes, level of competition), and formulating questions that the model should directly answer. The second stage is data collection, which consists of determining the necessary data for modeling, collecting data from various sources (statistical databases, observations), cleaning and processing data (eliminating errors and converting formats). The third stage refers to formalization, which consists of the selection of mathematical tools for modeling (for example, regression analysis, optimization models, stochastic processes), the formulation of mathematical equations that describe the relationships between variables, and the determination of model parameters (for example, regression coefficients). The fourth stage is modeling, which includes creating a model based on selected mathematical tools and obtained data, checking the model for compliance with reality (for example, using statistical tests), conducting experiments with the model to analyze its behavior and sensitivity. The fifth stage is model analysis, which consists of interpreting the obtained modeling results, identifying the main dependencies and trends, and assessing the accuracy and reliability of the model. The sixth stage means interpretation, which includes translating modeling results into a language understandable to the customer, formulating conclusions and recommendations based on the model. The seventh stage is model verification, which is characterized by comparing modeling results with real data, assessing the quality and accuracy of the model, and making changes to the model if necessary. The eighth stage is the use of modjeli, which involves using the model for forecasting, decision making, process optimization, monitoring and updating the model taking into account new data. And the final stage is model modification, which includes making changes to the model taking into account new data, goals and objectives, improving the model to increase accuracy and efficiency. It should also be taken into account that the quality of the model depends on the quality of the data and the correct choice of mathematical tools.

Regression models allow you to determine future sales volumes, optimize purchases, manage inventory, plan deliveries, also optimize costs by modeling the dependence of delivery costs on distance, analyze the efficiency of logistics processes by studying the influence of various factors, evaluate the impact of changes in logistics through modeling [2]. Pairwise regression is used to study the relationship of one variable to another. For example, the dependence of delivery time on distance. Multiple regression is used to study the dependence of one variable on several others [3]. For example, the dependence of delivery time on distance, cargo weight, time of day and traffic congestion.

Example 1: Calculating transportation costs using multiple regression.

Task 1. Determine transport costs for cargo delivery using multiple regression.

Data for calculation

Variable	Description	Meaning
Y	Transport costs	?
X1	Delivery distance	100 km
X2	Cargo weight	10 tons
X3	Times of Day	1 (day)
X4	Road congestion	0.8 (high)

We build a model: $Y = \beta 0 + \beta 1 * X1 + \beta 2 * X2 + \beta 3 * X3 + \beta 4 * X4 + \varepsilon$, where β0 is a constant value reflecting the basic delivery costs; β1 is a coefficient showing how delivery costs change with increasing distance; β2 is a coefficient showing how delivery costs change with increasing cargo weight; β3 is a coefficient showing how delivery costs change depending on the time of day; β4 is a coefficient showing how delivery costs change depending on road congestion; ε is a random error reflecting the influence of unaccounted factors.

Now let's start the calculation. Let’s assume that after analyzing the data, the following regression coefficients were obtained: β0 = 1000 BYN; β1 = 10 BYN/km; β2 = 50 BYN/ton; β3 = 200 BYN; β4 = 300 BYN, from which transport costs (Y) = 1000 + 10 * 100 + 50 * 10 + 200 * 1 + 300 * 0.8 = 2540 BYN.

Therefore, using a multiple regression model, it is possible to obtain a fairly accurate estimate of transport costs, taking into account various factors influencing their value. We will also further consider an example of the use of econometrics and economic-mathematical methods and models in logistics.

Example 2. Delivery route optimization.

Task 2. The company delivers goods throughout the city. Delivery routes need to be optimized to reduce time and fuel costs.

To solve this problem, we can build a model that predicts delivery time depending on distance, time of day, traffic congestion and other factors. In this case, we must collect and use data on previous deliveries – times, routes, time of day, traffic congestion, and then use a regression model that relates delivery time to factors influencing it. For example, Delivery time = $\beta 0 + \beta 1$ * Distance + $\beta 2$ * Time of day + $\beta 3$ * Traffic congestion + ε.

Based on the obtained model, it is possible to develop a route optimization algorithm that will select the optimal paths taking into account the predicted delivery time.

Example 3: Forecasting demand in a warehouse area.

Task 3. A logistics company plans to expand its warehouse space. It is necessary to forecast future demand for warehouse space to make investment decisions.

In order to solve this problem, we can use econometric models that will help predict the demand for warehouse space based on data from previous periods. To do this, we will need to collect data on the area of warehouses, volumes of stored goods, and the dynamics of growth in demand for warehouse space in previous periods. Next, we use the time series to forecast future demand values. For example, you can use an ARIMA model that analyzes autoregressive and moving averages [4]. Based on the constructed model, we will be able to obtain a forecast for the future period in order to make an informed decision on expanding warehouse space.

Causal forecasting methods in logistics focus on identifying cause-and-effect relationships between factors influencing logistics performance and the performance indicators themselves. This allows us not only to predict future values, but also to understand how changes in certain factors will affect the result, for example, we can determine the optimal size of the delivery lot, predict demand taking into account marketing campaigns, evaluate changes in the transport network, and so on [5]. Let us further consider using example 4 the solution to problem 4.

Example 4. The company wants to assess the impact of changes in the price of a certain product on the demand for this product and, accordingly, on sales volumes.

First, we need to collect data on product sales for a certain period, including product price, sales volumes, marketing activities (advertising, discounts), seasonal factors (for example, holidays). Next, we choose the causal method; in this case, we can use the Regression Discontinuity method, which is suitable for analyzing the impact of price changes on demand. The data is divided into two groups: with the price before the change (control group) and with the price after the change (experimental group). Using regression analysis, the impact of price changes on sales volumes is assessed, excluding the influence of other factors (seasonality, marketing). The results of the analysis will allow us to determine how significantly the price change affected the demand for the product.

Optimization models that reduce to a transport problem model help in resource allocation; the transport problem model can be used to model the distribution of resources between production units (origin points) and projects (destination points). Moreover, optimization models contribute to production planning, where it can be used to model the allocation of production capacity between different types of products (shipping points) and sales markets (destination points). These models can also be used for warehouse management, for example, modeling the distribution of goods across different compartments of the warehouse (dispatch points) taking into account the frequency of requests for each type of product (destination points) [6].

Thus, we can conclude that econometrics and economic-mathematical modeling is an important aspect for forecasting, analysis and evaluation of indicators in logistics. Thanks to econometrics, given the necessary data, we can calculate many logistics tasks and find the optimal option, which makes logistics efficient and more competitive. Economic and mathematical modeling helps to assess risks and uncertainty in logistics, for example, you can model the impact of changes in the exchange rate on the cost of importing goods or the impact of supply instability on warehouse inventory. This allows you to develop risk management strategies and reduce their negative impact on the business. Linear econometric models are widely used in logistics because they are relatively easy to understand and interpret. Regression coefficients have a clear meaning and show the degree of influence of independent variables on the dependent variable. Moreover, linear models are computationally efficient and require less computational resources compared to nonlinear models, which is an important point for logistics, where it is often necessary to quickly obtain modeling results for making operational decisions. In logistics, large amounts of data on costs, transportation volumes, delivery times and other parameters are often available, so linear models are well suited for analyzing such data and making forecasts. However, they may not be accurate enough to describe the complex non-linear dependencies that occur in logistics. In such cases, nonlinear models can be used, for example, regression with a polynomial function. And we must also take into account that these models must be used with specific data in order to obtain the necessary results.

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